AD NUMBER

AD829014

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Critical Technology; 20 DEC 1957. Other requests shall be referred to Air Force Space and Missile Systems Organization, Attn: SMSD, Norton AFB, CA 90045.

AUTHORITY

samso, usaf ltr, 28 feb 1972

AD829014

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of: Hq.SAMSO, LA., Ca. 90045 Attn: SMSD

CONVAIR

A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO

CONVAIR

A DIVISION OF GENERAL DYNAMICS CORPORATION

SAN DIEGO Div.

REPORT RT-318

DATE 20 December 1957

MODEL 7

TITLE

RESULTS OF TESTS

ON

ATLAS MISSILE SKIN TEMPERATURE GAGES,

Model 7.

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of: Hq.SAMSO, LA., Ca. 9004[illegible] Attn: SMSD

PREPARED BY K. C. Hendershot
K. C. Hendershot

GROUP Thermodynamics Laboratories

REFERENCE

CHECKED BY Roy F. Holmes
R. F. Holmes

APPROVED BY W. L. Dittmann
W. L. Dittmann

NO. OF PAGES

NO. OF DIAGRAMS

REVISIONS

NO.	DATE	BY	CHANGE	PAGES AFFECTED

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

I. INTRODUCTION

During flight tests of the Atlas missiles, it will be necessary to measure and telemeter to ground receiving stations numerous surface temperatures at various locations on the missile skin. It has been proposed that temperature sensitive platinum resistance gages be attached to the missile surfaces to perform this function. Since these temperature gages will be exposed to aerodynamic heating and high velocity air flow, they must of necessity be strong and well-bonded to the missile surface. In order to investigate the adequacy of the proposed gage installations, a series of tests has been conducted at the Thermodynamics Laboratory in which the gages have been subjected to an environment similar to that which they will encounter during actual missile flight.

II. SUMMARY

From the tests which have been conducted, it appears that gage installations having no post-application temperature cure have insufficient strength to remain bonded to the missile skin when exposed to a relatively low velocity flow of heated air over the surface. However, curing of the gage installations at moderate temperatures (400-600°F) increased the bond strength to such a degree, the gages remained firmly attached to the skin sample after continuous exposure to a 1000°F air flow having a dynamic pressure of approximately 200 lb/sq. ft. for a period of three minutes. Temperatures indicated by the test gages were lower than the actual skin temperatures during transient heating conditions, but approached true skin temperature fairly closely when steady state heating conditions were achieved.

III. TEST EQUIPMENT & PROCEDURE

A number of .016 inch thick stainless steel panels having skin temperature gage installations typical of those proposed for use on the Atlas flight test missiles were supplied for testing by the Astronautics Data Transmission Group. The platinum resistance gages, Ref. CVAC Part No. 701259-5, are produced by Trans-Sonics, Inc., Lexington, Mass.; have a nominal room temp resistance of about 55 ohms; and provide a resistance change of about 0.1 ohms per °F over their working range of -300°F to 900°F. The gages are applied directly against the surface of the skin and are backed with a protective cloth covering impregnated with a silicone adhesive. Chromel-alumel thermocouple junctions were spotwelded onto the test panels as follows: T/C #1, attached to the back side of the panel, directly under the temperature gage; T/C's #2 and #3 attached to the panel upper surface, 1 inch ahead of and 1 inch to the side of the center of the gage, respectively. The panel was located immediately downstream of a two-dimensional convergent-divergent nozzle having an exit 3.05 inches wide and 0.725 inches high (Figure 1). The panel was mounted with its surface parallel to the lower lip of the nozzle, with the temperature gage approximately two inches downstream of the nozzle exit. Air at any temperature between ambient and 1000°F., at velocities from Mach 0 to 0.40 and M = 1.94, and

dynamic pressures from 0 to 5600 lbs/sq. ft. was available from the nozzle during the tests. A shielded chromel-alumel thermocouple junction, located downstream of the gage just above the surface of the test panel, was used to determine the temperature of the heated air flowing over the test specimen.

The platinum resistance element of the temperature gage was connected as one leg of a Wheatstone bridge having an output sensitivity, $\Delta E/\Delta R_G$, of approximately 1.1 MV/ohm. The bridge was calibrated periodically by replacing the resistance gage leg of the bridge with a series of different, accurately known resistances and noting the corresponding bridge output. The outputs of the thermocouples and transducer bridge were continuously recorded during each test with an Offner direct writing oscillograph recorder. Conversion of the thermocouple voltage outputs to the equivalent temperatures were made with the standard temperature - EMF tables for Chromel-alumel thermocouples. Standard temperature-resistance characteristics for platinum wire (See Fig. 2) were used to convert the temperature gage resistance changes to the corresponding temperature changes.

A total of seven gage specimens were tested under varying temperature and dynamic pressure conditions. Individual tests varied from 10 to 180 seconds duration. Nearly all specimens were subjected to a number of consecutive tests of increasing duration and severity of test conditions before failure occurred. A "step" temperature input was applied to the test specimens by means of a large two-way valve located upstream of the air flow nozzle. The pressure and temperature of the air stream were adjusted to the desired test conditions with the valve in a by-pass position. Following this, the valve was rapidly rotated to divert the hot air from the by-pass outlet to the flow nozzle and provide essentially a "step" heat input to the temperature gage.

IV. RESULTS AND DISCUSSION

Early in the test program, it became obvious that the proposed uncured gage installations had insufficient mechanical strength to withstand exposure to air temperatures in the range of 200-300°F (see Table I). All four of the uncured gage specimens that were tested peeled loose from the test panels after less than 30 seconds exposure to air temperatures below 400°F and at free stream dynamic pressures only about one-half as large as are anticipated during actual missile flights. Figure 3 shows typical failures of two of the uncured gage specimens. The gage on the top panel, specimen #1, came loose from the surface and was completely destroyed after only 5.5 seconds exposure to a 200°F, q = 550 lbs/sq. ft. air flow. Note that even the covering over the gage leads failed under these conditions. Gage specimen #2 on the lower panel failed after 23.5 seconds exposure to a lower velocity (q = 59 lbs/sq. ft.), but considerably hotter (350°F) air stream. Only the material actually

covering the gage itself loosened under these conditions, while the remainder of the cloth covering remained relatively intact. The white material near the downstream end of the gage leads is Sauereisen cement, applied to protect the area where the leads passed through holes in the test specimen from the surface to the underside. An additional series of tests was conducted with a fifth uncured specimen while flowing unheated air over the surface at dynamic pressures up to 5000 lb/sq. ft. No damage or loosening of the gage was observed even after several minutes exposure to the high velocity flow, thus indicating the rapid failure of the other gages must have resulted primarily from high temperature deterioration of the elements rather than from erosive action from the air stream.

Following these initial unsuccessful tests, three additional test samples having two different post cure treatments were prepared and tested. The post cures consisted either of heating the panels and installed gages at a temperature of 450°F for 30 minutes or 650°F for 15 minutes. Gage #6 (see Fig. 4) having the 650°F - 15 minute cure was subjected to a series of tests with increasingly higher air temperatures, finally being exposed to an air temperature of 870°F and dynamic pressure of 214 lbs/sq. ft. for a period of 180 seconds without failure. Of the two specimens cured at 450°F for 30 - 40 minutes, one sample (No. 5 in Fig. 4) satisfactorily withstood a 1000°F., q = 213 lbs/sq. ft. air flow for 180 seconds with no failure of the gage and only slight loosening of the leads. The other sample (No. 7 in Fig. 4) was subjected to two successive runs of 120 and 180 seconds at gas temperatures of 700 and 1100°F., respectively, and finally to a gas temperature of 1300°F before loosening of the gage and failure occurred after 39 seconds exposure.

In all of the tests described above, the air flow was directed parallel to the gage leads. However, since some gage locations on the flight missiles may require routing the gage leads circumferentially around the outer surface, a limited number of tests were conducted with the air flowing laterally across the gage leads. Under these cross-flow conditions, no failures of the temperature cured gage installations were encountered at gas temperatures below 700°F and dynamic pressures to 200 lbs/sq. ft. However, at a gas temperature of 850°F, the leads loosened and blew away after only 10 seconds exposure to the air flow.

Temperature-time histories for the free stream, gage and two skin temperatures during several typical test runs are shown in Figures 5 - 10. In Figure 5, during run No. 1, unintentional variation of the free stream temperature provided a good indication of the response characteristics of the gage installation. Figures 6 - 10 indicate the gage response when exposed to step temperature inputs of various magnitudes. In general, response of the temperature gages when subjected to a relatively rapid temperature increase was good, although the temperature indicated by the gage definitely lagged the temperature of the skin which was exposed to the free stream by varying amounts of time. It was also observed, as would be expected, that during transient heating

conditions, the temperature of the skin directly beneath the transducer remained considerably cooler than other skin areas because of the good insulating characteristics of the relatively thick gage installations.

IV. CONCLUSIONS:

Although only a limited number of temperature gages were tested, and these at relatively low free stream temperatures and pressures (compared to conditions which will be encountered at high supersonic Mach numbers), enough information has been obtained to arrive at the following general conclusions:

1. The gage installations in the uncured condition have insufficient bonding strength to remain attached to the missile skin when exposed to a low temperature, low velocity air flow.

2. Temperature curing of the gage installations after application on the missile skin will provide sufficient additional strength to allow the gages to satisfactorily withstand a high temperature (1000°F) and relatively high velocity air flow. However, it is possible that temperature curing of the gage installations may adversely affect the physical characteristics of the transducer as evidenced by the fact that two of the three temperature-cured gage specimens which were tested exhibited erratic and unreliable resistance characteristics following their cure. A more complete investigation of possible detrimental effects on the gages resulting from temperature curing should certainly be made before large numbers of gages are installed on the missile.

3. Due to the large thermal capacity and low conductivity of the transducer covering, transient response of the gages to changing skin temperatures will not be as rapid or as accurate as would be obtained with thermocouples attached directly to the missile skin. However, use of the resistance gages has the advantage that the transducer element need only touch the missile skin, and does not, as would be the case if thermocouples were used, require spotwelding or other fastening techniques which might disturb the structural integrity of the thin missile tank walls.

4. The relatively thick gage leads and their covering, particularly those that must be routed circumferentially around the missile body cross-wise to the free stream air flow, may loosen and fail more readily than the gages themselves.

5. Output sensitivity of the transducer is high when installed

in a suitable bridge. An output of approximately 0.25 mV/°F was readily obtained with the simple bridge used in these tests. This compares to an output of about .03 mV/°F from an iron-constantan thermocouple, or a sensitivity about 8 times as great.

6. At the time these tests were conducted, at least as far as the writer could determine, there was an apparent lack of reliable temperature-resistance calibration data for these platinum resistance gages. If this situation has not been corrected, certainly every effort should be made to insure that sufficient data is available to make accurate resistance to temperature conversions.

SUMMARY OF TEST CON

TABL

All temps. are fin

RUN	DURATION (sec.)	SPECIMEN	CURE	Tair(°F)	T_1(°F)
1	76	#1	None	200	175
2	25	"	"	185	151
3	54	"	"	190	167
4	33.5	"	"	145	112
5	5.5	"	"	200	110
6	31	#2	"	135	105
7	36	"	"	255	203
8	23.5	"	"	349	215
9-19	60-90	#3	"	70	70
20	70	"	"	-	-
21	35	"	"	-	-
22	30	"	"	-	-
23	35	"	"	-	-
24	30	"	"	-	-
25	32	"	"	-	-
26	15	"	"	-	-
27	180	#4	"	175	-
28	180	"	"	350	289
29	180	"	"	200	165
30	< 5	"	"	355	-
31	180	#6	15 min.@ 650°F	385	315
32	180	"	"	377	325
33	180	"	"	515	340
34	180	"	"	785	515
35	180	"	"	870	545
36	180	#5	40 min.@ 450°F	455	315
37	180	"	"	735	540
38	180	"	"	1010	745
39	10	#10	15 min. @ 600°F	850	-
40	180	"	"	705	-
41	121	#7	30 min.@ 450°F	733	446
42	180	"	"	1080	[illegible]
43	39	"	"	1345	1005

A

TEST CONDITIONS AND RESULTS

TABLE I

. are final temps. @ end of run.

T_1(°F)	T_2(°F)	T_{Gage} (°F)	q(lbs/sq.ft.)	COMMENTS
175	169	168	142	Gage OK.
151	153	159	-	Gage still in good condition.
167	160	170	125	" " " " , "
112	121	123	625	Lead wires loosened slightly. Gage OK.
110	197	144	550	Gage failed.
105	129	127	38	Gage and leads OK.
203	215	232	59	Gage still OK.
215	154	248	59	Gage failed.
70	70	70	38-5000	Cold flow tests. Gage and leads OK @ all test conditions.
-	88	-	43)	
-	115	-	43)	T/C #2 only used during these
-	167	-	43)	tests. Transducer not functioning
-	163	-	48)	properly. Gage OK 20-23.
-	250	-	48	Covering becoming soft and tacky and slightly loose.
-	285	-	48	Covering very soft and loose.
-	320	-	54	Gage and leads failed.
-	-	-	60	T/C's not operating. Gage and leads OK.
289	324	298	66.	Gage OK-Soft and tacky, however.
165	180	182	108	Gage OK.
-	-	-	143	Gage failed at start of run.
315	345	Erratic	143	Gage and leads OK - erratic operation of gage, however.
325	332	-	> 200	Gage still OK - no signs of loosening.
340	410	-	142	Gage OK-not operating electrically, however.
515	605	-	171	" " " "
545	700	-	214	Gage still OK - Discontinued tests on specimens.
315	420	-	171	Gage OK-Doesn't work electrically, however.
540	630	-	213	Gage OK-Somewhat soft.
745	840	-	213	Leads loosened @ about 30 sec. Gage remained tight, however.
-	-	-	100	Cross flow over gage leads. Loosened and failed @ 10 sec. No gage or T/C's on specimen.
-	-	-	202	Gage leads OK-no loosening.
446	-	532	210	Gage & leads OK-No loosening. T/C #2 inoperative.
740	-	785	170	Gage & leads still OK.
1005	1105	920	165	Gage failed @ 39 sec.

B

FIG. 1 Convergent - Divergent Nozzle

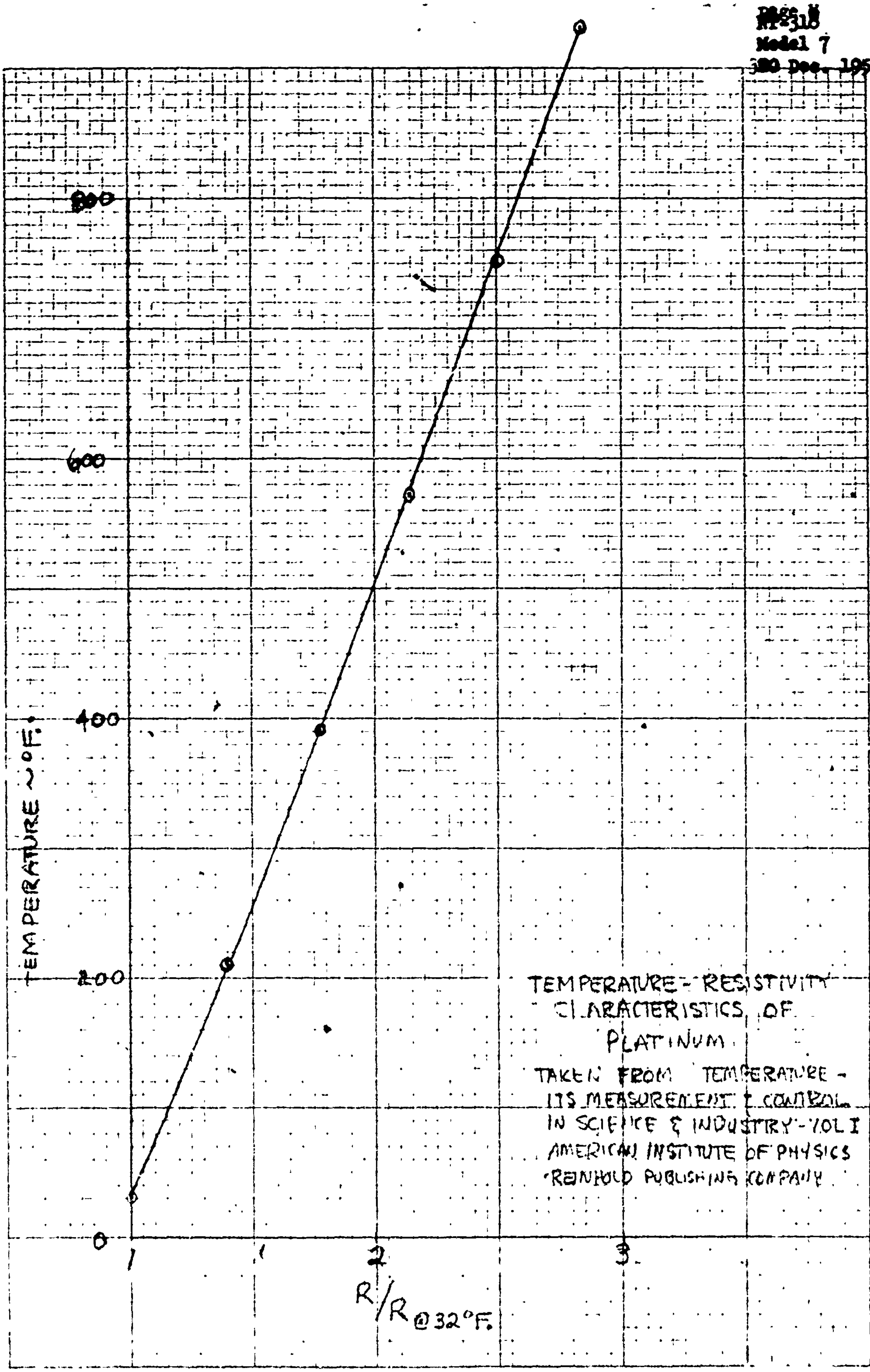
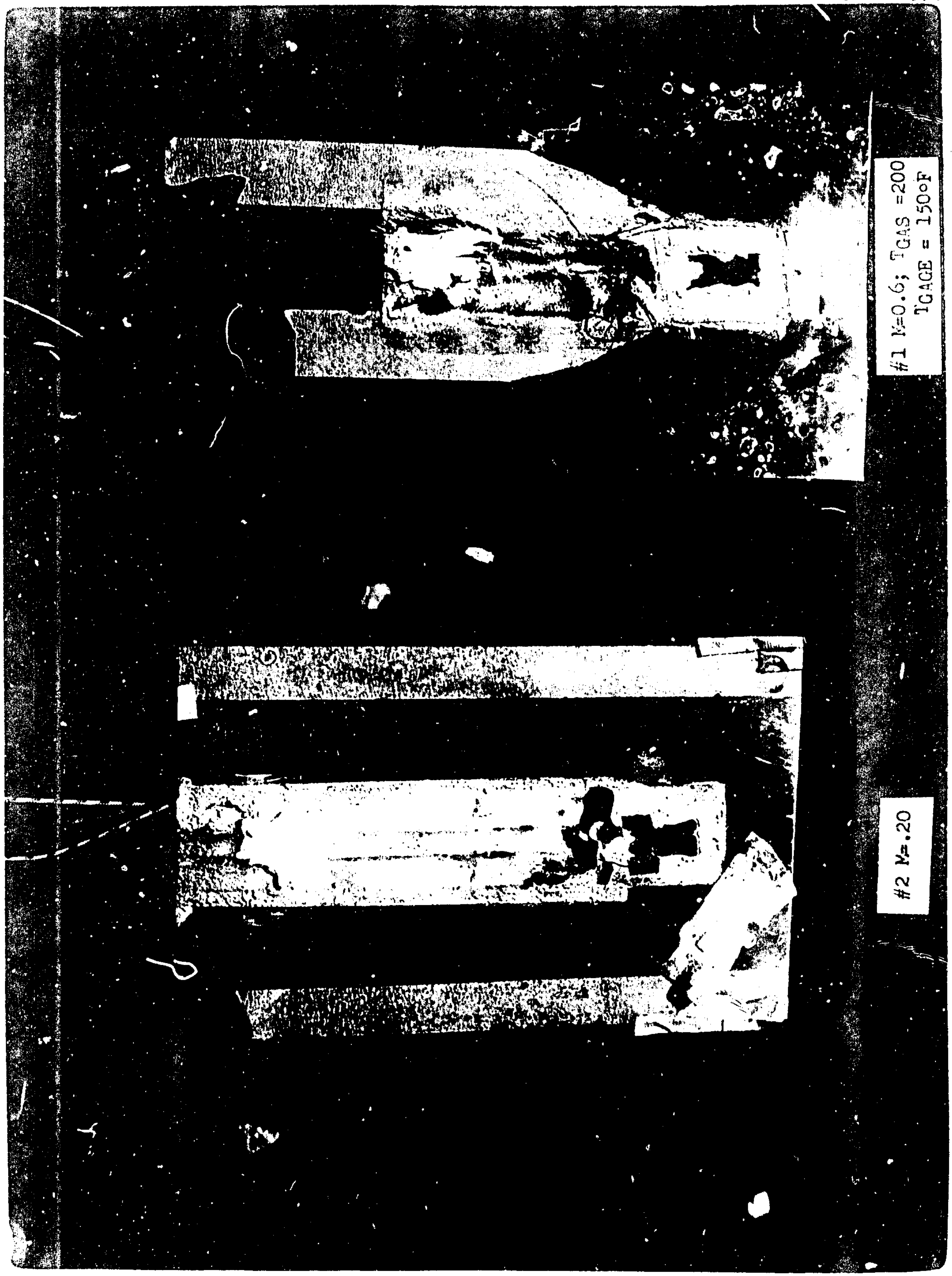


FIG. 2 Temperature - Resistivity Characteristics of Platinum


#1 M=0.6; TGAS =200
TGAGE = 150°F
#2 M=.20

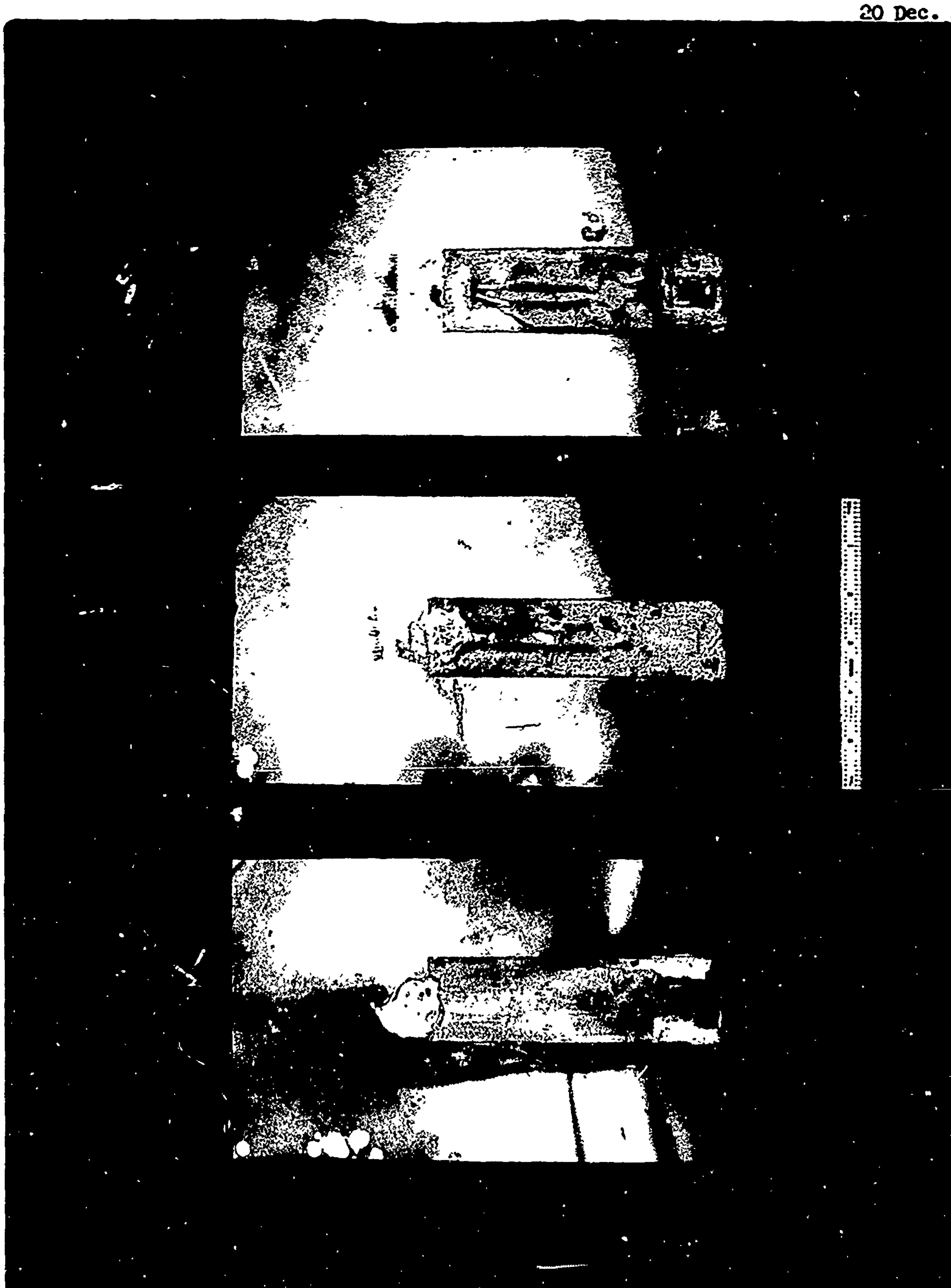


FIG. 4 Typical Cured Gage Specimens

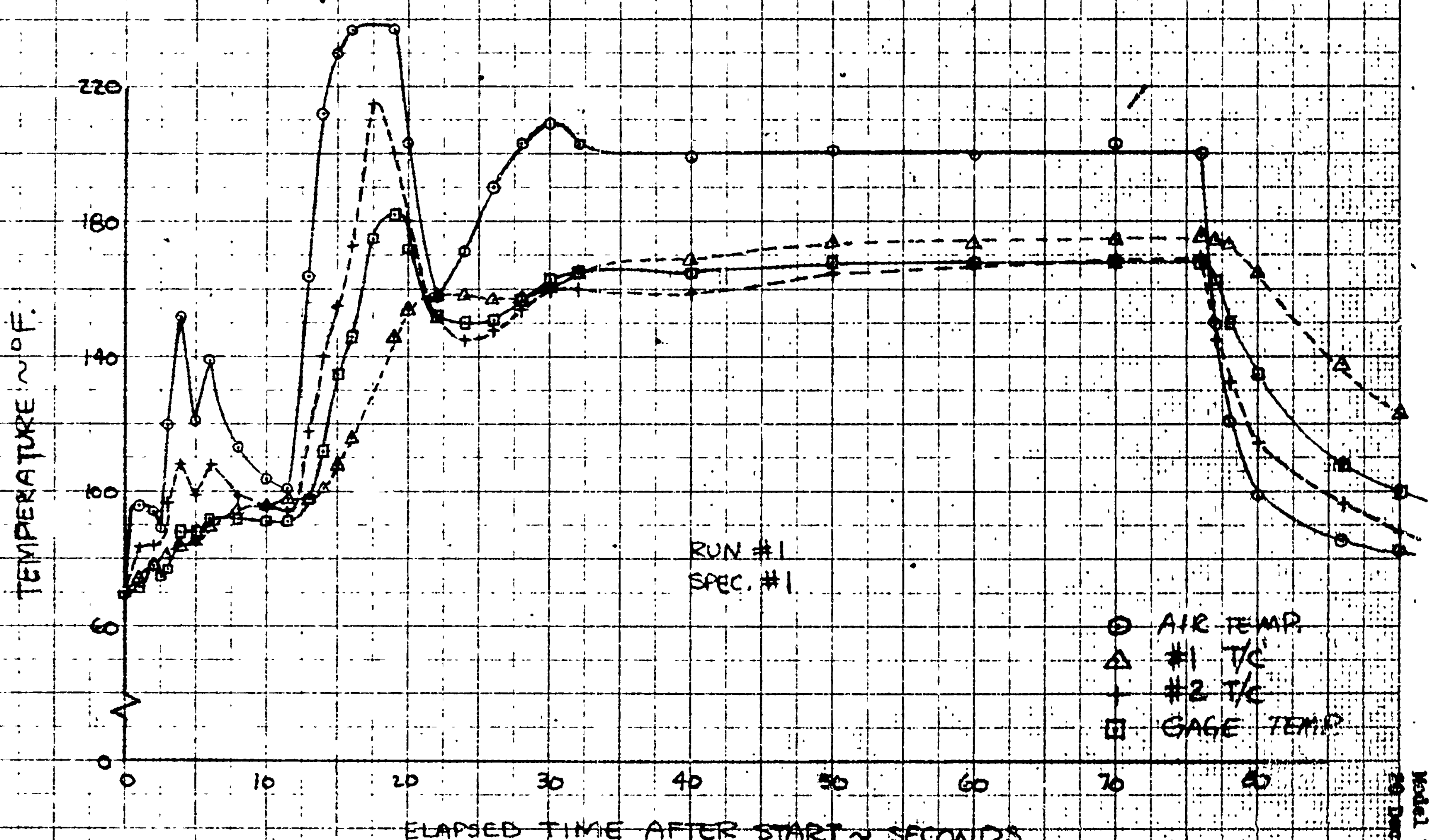


FIG. 5 . TEMPERATURE - TIME HISTORY

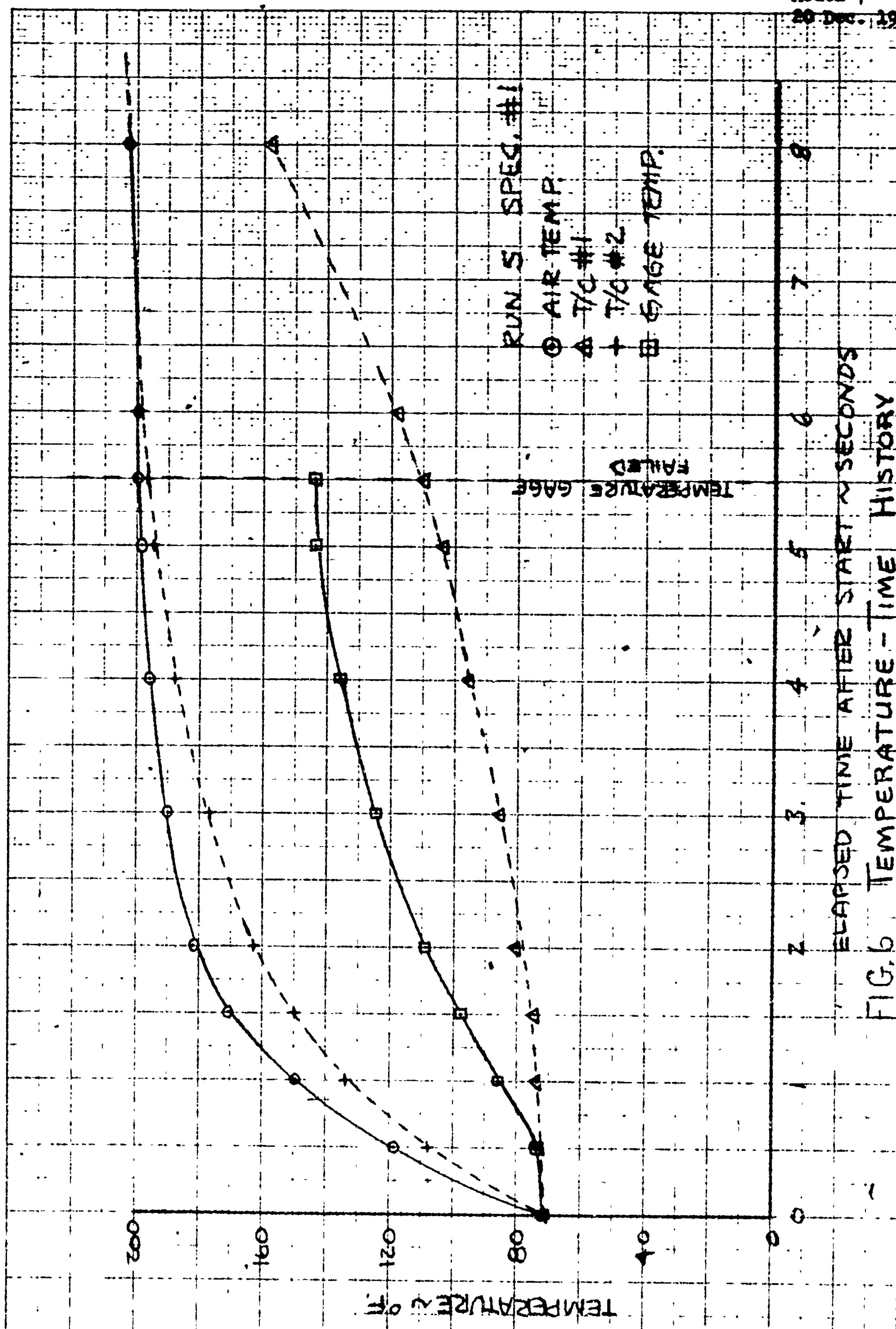


FIG. 6 TEMPERATURE - TIME HISTORY

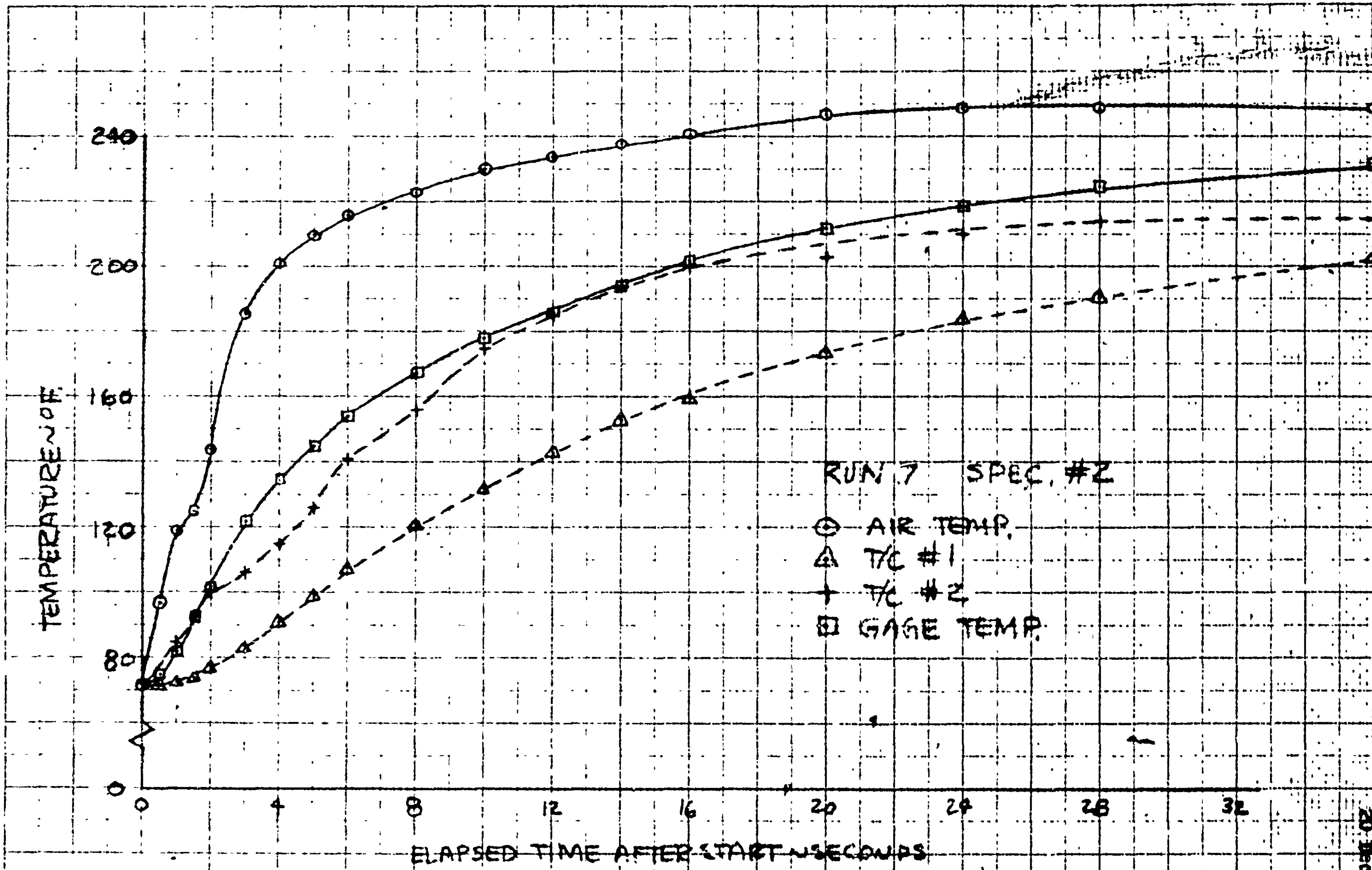


FIG. 7 TEMPERATURE - TIME HISTORY

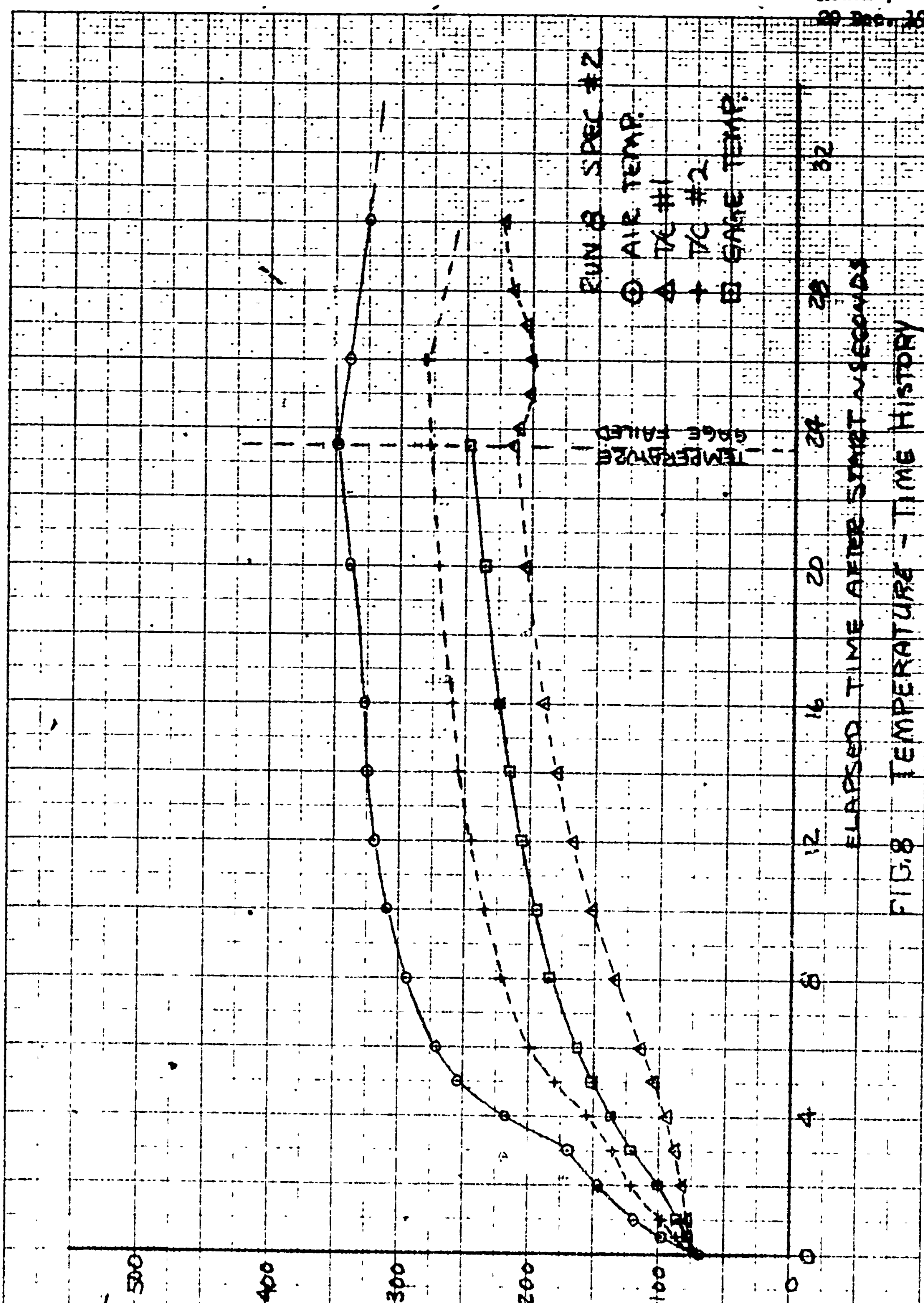


FIG. 8 TEMPERATURE - TIME HISTORY

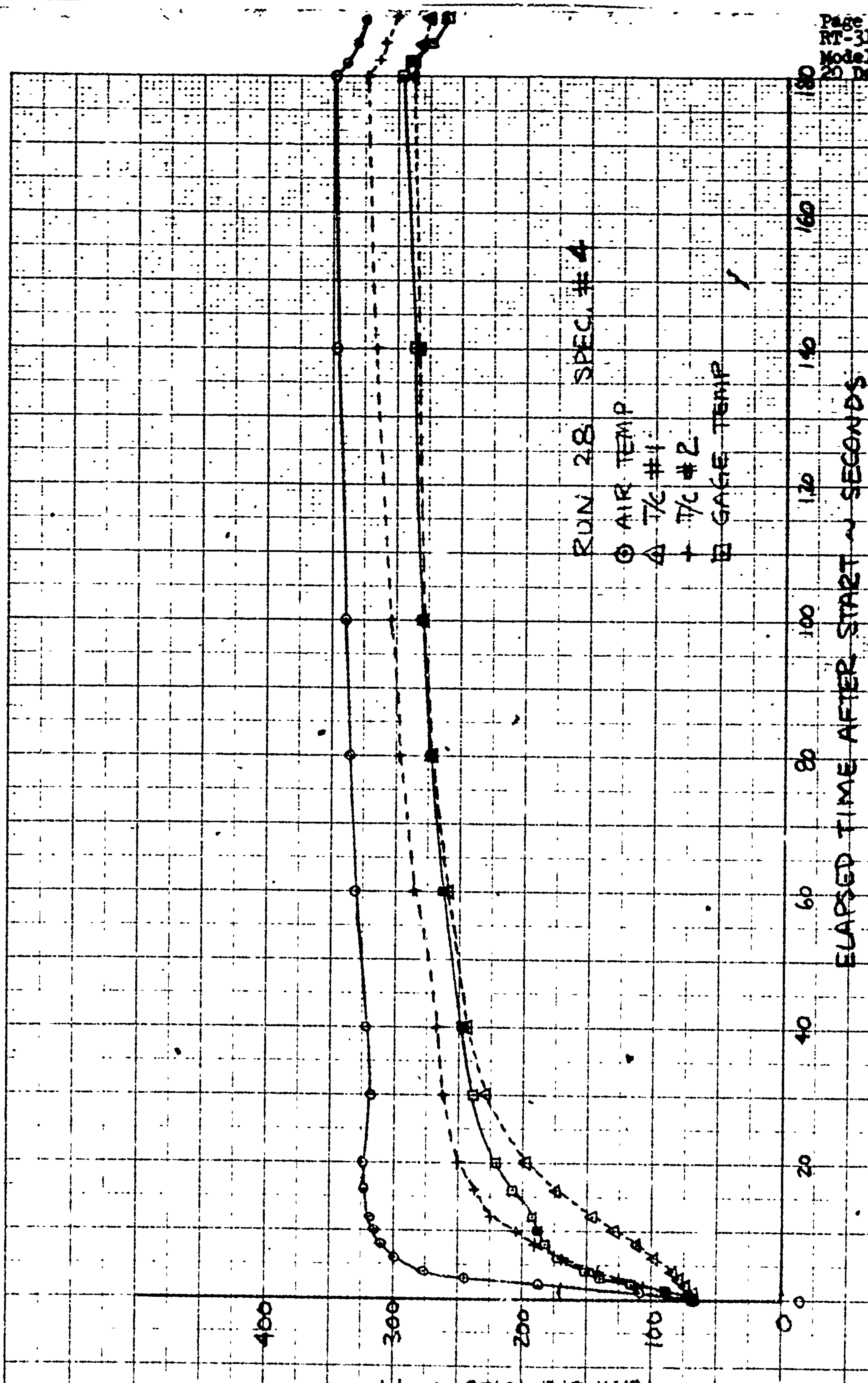


FIG. 9 TEMPERATURE - TIME HISTORY

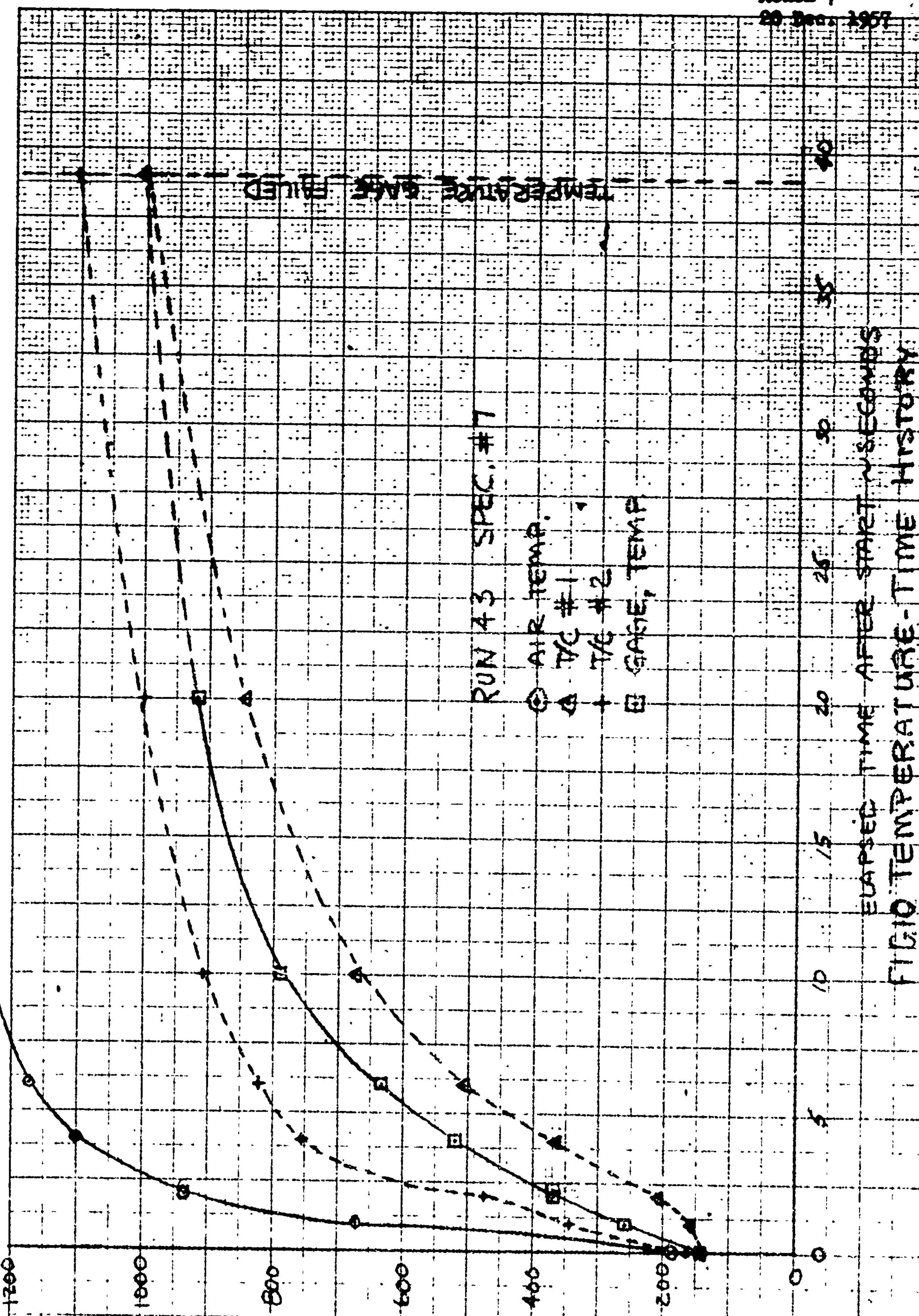


FIG 10 TEMPERATURE-TIME HISTORY